GENERAL MOTORS CORPORATION

GM DEFENSE RESEARCH LABORATORIES

AEROSPACE OPERATIONS DEPARTMENT

EXPERIMENTAL INVESTIGATIONS OF SIMULATED METEOROID DAMAGE TO VARIOUS SPACECRAFT STRUCTURES

PROGRESS REPORT NO. 2

FOR PERIOD ENDING 30 NOVEMBER 1964

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Scope of Program

The physics of interaction of a meteoroid with a relatively thin metallic shield and the damaging effects of the debris that passes through the shield will be investigated using analytical and experimental techniques. The influence of particle and target density, porosity, and heats of fusion and vaporization will be included in the investigation; and the relative efficiency of various structural concepts compared. The range of impact velocities to be investigated experimentally will be up to 8.0 km/sec. The primary objective of the investigation is the establishment of design criteria and equations to define the penetration mechanics of meteoroids into typical spacecraft structures.

Accomplishments During the Reporting Period

The effects of impulse loading on pretensioned beams are presently under investigation. Preliminary results indicate the following trends:

a) The maximum displacement of the beams are reduced significantly as shown in Figure 1. For this analysis, the beams were pretensioned to a given percentage of the yield stress of the material. Results are shown for stresses of 25%, 50%, 75%, and 100% of yield stress.

b) The required backup plate thickness under a pretension of 100% of yield stress increases approximately 6% if the criterion of no yield is imposed, and approximately 70% if the fracture criterion is used. These results are shown in Figure 2.

The results of experiments conducted during the reporting period are summarized on the attached data sheets. Experiments to determine the effects of projectile and shield melting and vaporization were conducted with cadmium projectiles against cadmium shields. Shot No. D-1045 produced conditions such that the cadmium should be vaporized when it strikes the backup structure. This condition produced a momentum multiplication of 1.42, much less than the 2.0 maximum predicted. Shot No. D-1046 resulted in liquid debris striking the backup structure and gave a momentum multiplication of 1.16, again quite low. As a test of the use of cadmium to simulate very high velocity impacts, tests were performed to measure the stress in the wave reaching the back surface of the backup structure with cadmium projectiles and shields. The stress was measured using the throw-off pellet technique. Two measurements

were made (D-1048 and D-1049). The projectile size was adjusted to match the momentum felt by the backup (actually, the higher velocity was about 1.1 times the momentum of the lower velocity). At the high velocity, no spall formed and a pressure of 7.7 kilobars was measured. At the low velocity, a spall formed and a stress of 22 kilobars was measured. These initial tests give some confidence in the use of momentum scaling to simulate high velocity thin sheet impacts.

Preliminary density tests show that density effects are detectable at velocities up to 7 km/sec.

Proposed Program for the Next Reporting Period

During the next reporting period, 1 December 1964 through 31 January 1965, the computer program for determining the response of a plate to an impulse load will be employed to check the results obtained previously using the strip approximation. The program will also be compared to experimental results.

Experiments will be performed to determine the distribution of momentum on the backup, the accuracy of the strip approximation and the effects of projectile density.

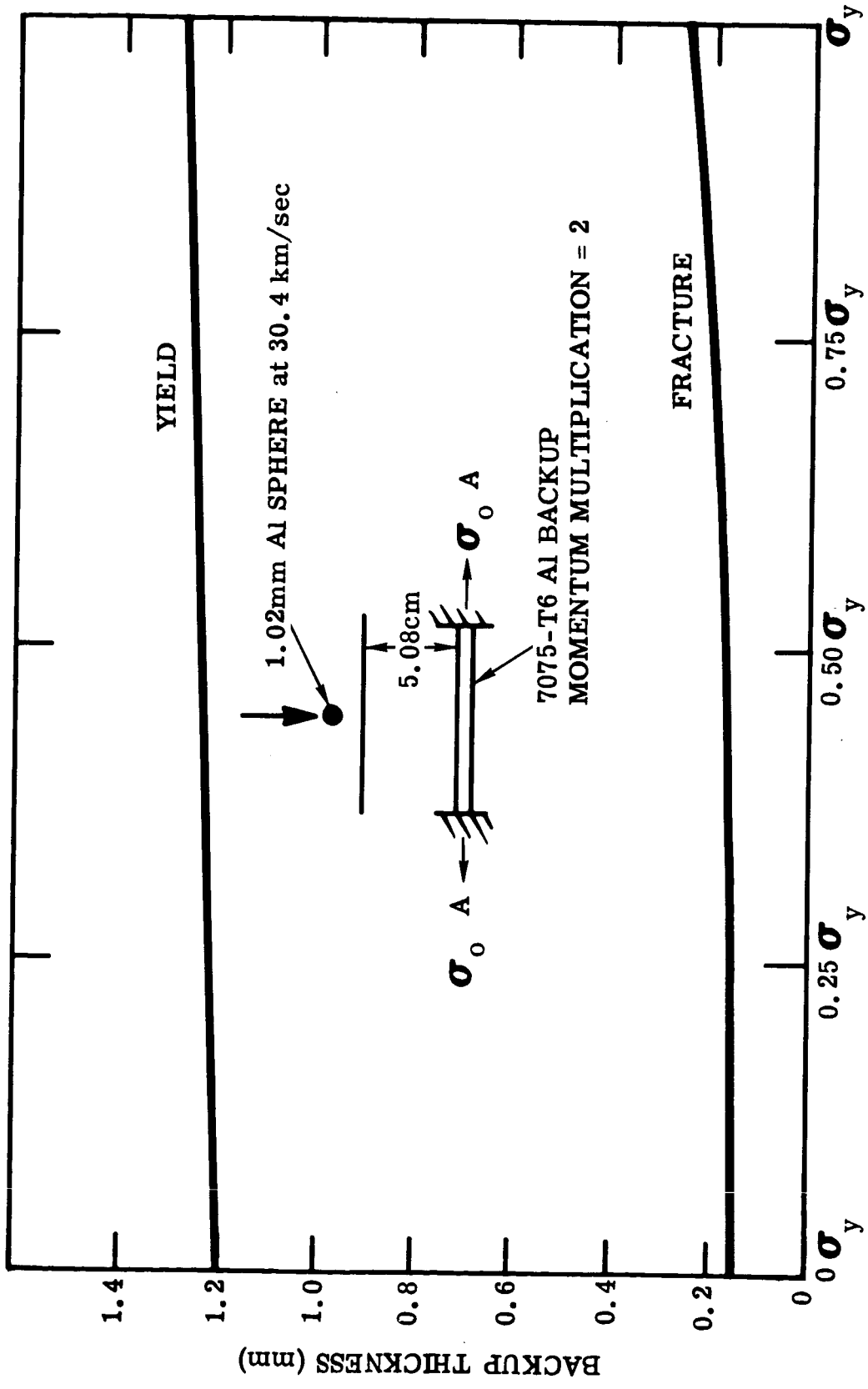

FIGURE 2 BACKUP THICKNESS VS PRETENSION STRESS

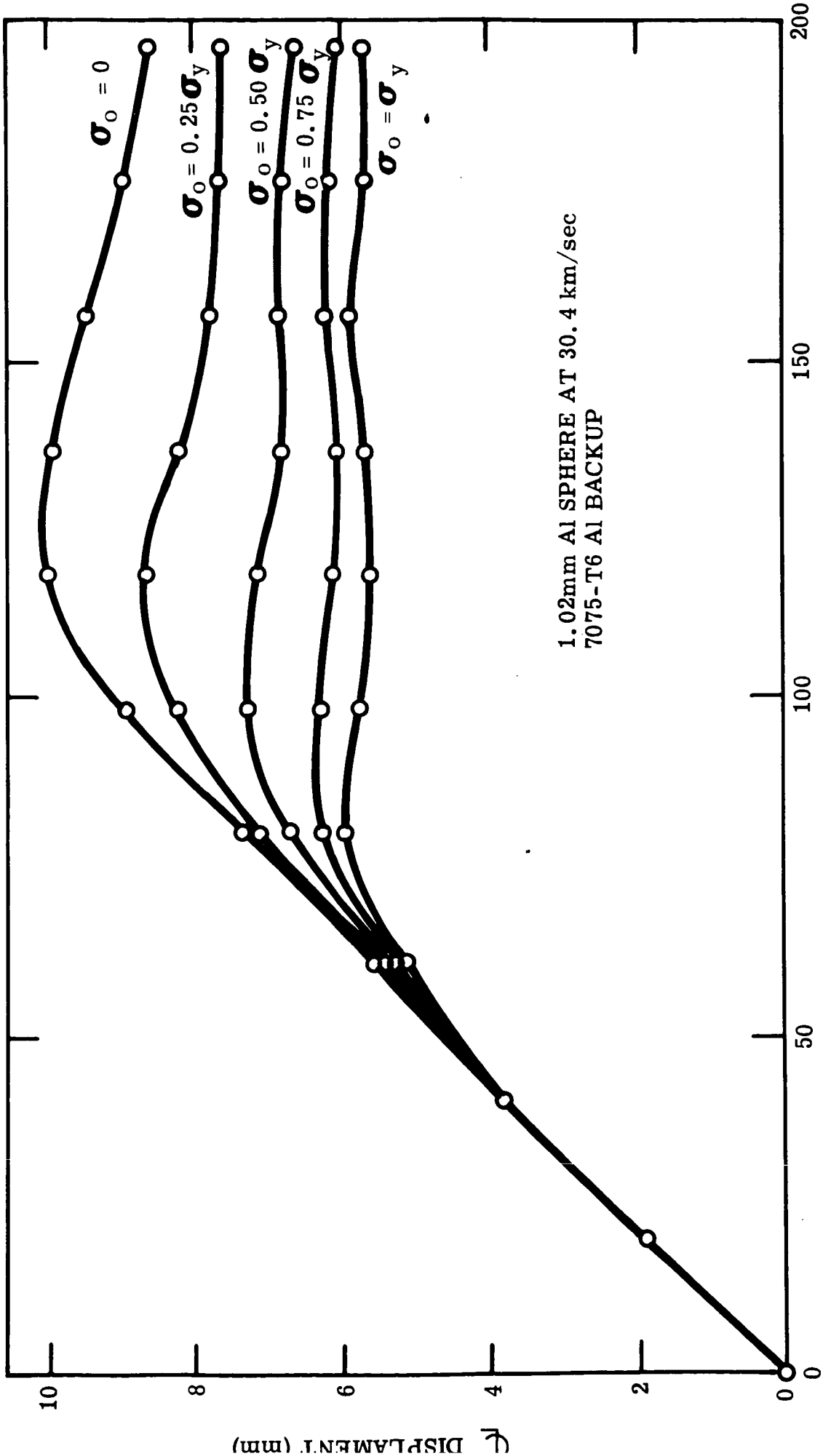

FIGURE 1 CENTER LINE DISPLACEMENT VS TIME-PRETENSIONED BEAMS

SHOT NO.	PROJECTILE MATERIAL	DIAMETER (mm)	SHIELD MATERIAL	THICKNESS (mm)	SPACING (cm)	BACKUP MATERIAL	THICKNESS (mm)	VELOCITY (km/sec)	TOTAL PENETRATION (mm)	HOLE SIZE (mm)	SPRAY DIAMETER (mm)	SPRAY ANGLE	MV/mv	REMARKS
D-1044	Cd	3.18	Cd	0.635	5.08	7075-T6	12.7	5.48	0.66	7.6	97	87°		
1045								6.40	.69	7.6	99	89	1.42	
1046								3.18	.86	7.0	91	83	1.16	
1047							6.35	6.49	.76	7.6	97	87		
1048		4.0		.762				3.44	.81	7.9	127	103		
1049		3.18		.635				6.46	.89	—	94	86		PISTON HIT
1050	Ti	2.62	1100-0	1.02				—	—	—	—	—		NO IMPACT
1051	Cu	2.08						4.17	3.30	5.1	86	81		
1052	Ti	2.62						3.49	2.92	5.1	76	74		
1053								7.25	2.03	—	89	83		PISTON HIT
1054	Cu	2.08						7.10	2.06	6.4	83	79		
1055	Al	3.05						7.16	1.04	9.4	95	86		
1056								3.62	1.40	7.1	66	66		
C-722		3.18		.635				7.93	.71	4.8	95	86		
723							4.75	7.41	.89	4.8	—	—		
725				1.02			.813	7.02	—	—	—	—		PISTON HIT
726								5.43	∞	7.9	—	—		
D-1114	NYLON	4.19					6.35	2.92	1.19	7.9	53	56		
1115								6.10	1.17	9.7	102	90		
1116								6.80	1.27	10.9	108	94		
1117	Al	3.18		.635			12.7	3.26	2.49	5.1	56	58		
1118								3.11	2.90	5.1	56	58		
1119								3.29	1.57	5.1	61	62		
1120								3.38	2.82	5.1	61	62		
1121								5.61	1.85	6.4	86	81		
1122								5.64	1.22	6.4	84	79		
1123								5.61	1.65	6.4	85	80		

SHOT NO.	PROJECTILE MATERIAL	DIAMETER (mm)	SHIELD MATERIAL	THICKNESS (mm)	SPACING (cm)	BACKUP MATERIAL	THICKNESS (mm)	VELOCITY (km/sec)	TOTAL PENETRATION (mm)	HOLE SIZE (mm)	SPRAY DIAMETER (mm)	SPRAY ANGLE	MV/mv	REMARKS
D-1124	Al	3.18	1100-0	0.635	5.08	7075-T6	12.7	5.78	0.81	—	81	77°		PISTON HIT
1125								7.50	.84	6.6	76	74		
1126								—	—	—	—	—		NO IMPACT
1127								7.32	1.02	—	89	83		PISTON HIT
1128								7.29	.74	6.6	89	83		